Predicting the Output Error of a Coriolis Flowmeter under Gas-Liquid Two-Phase Conditions through Analytical Modelling




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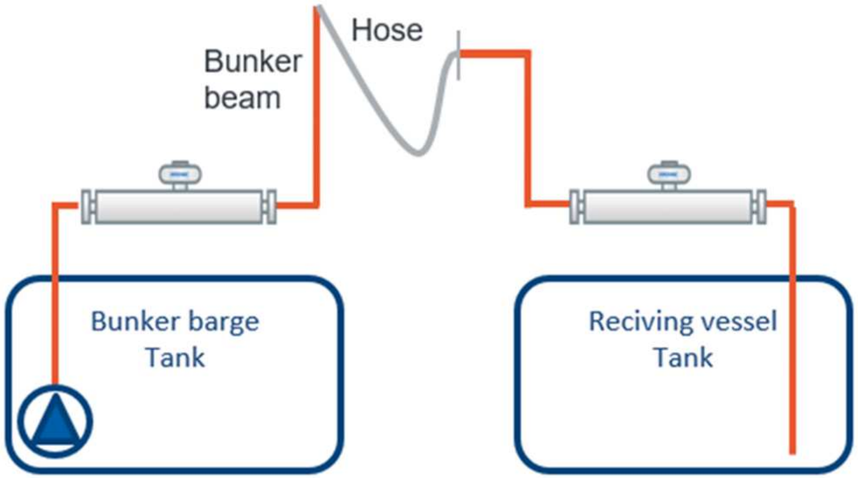
Outline

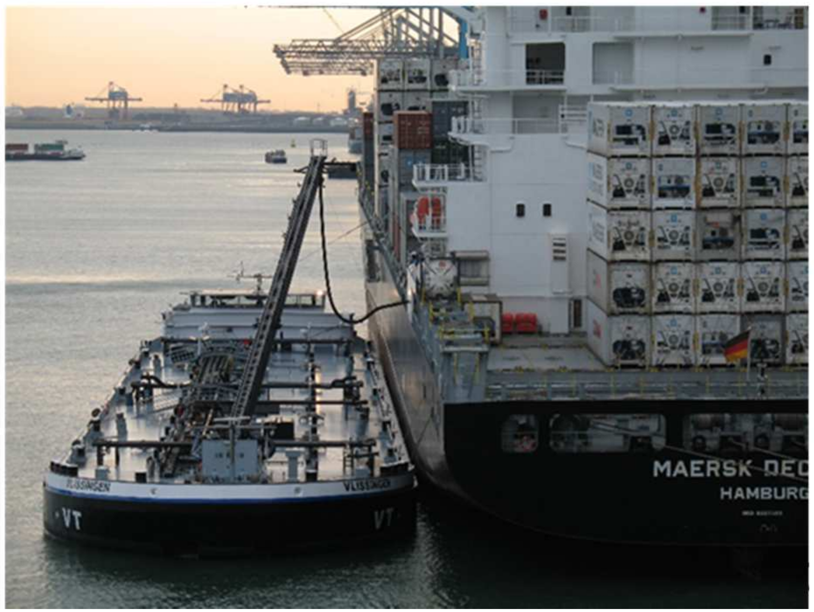
- Introduction
- Methodology
- Experimental Work
- Data Interpretation
- Conclusions

Introduction

Gas-liquid two-phase flow

- Complex, liquid dominant flow (0-40% GVF)
- Unavoidable in many industrial processes
- Low uncertainty in overall measurement is required

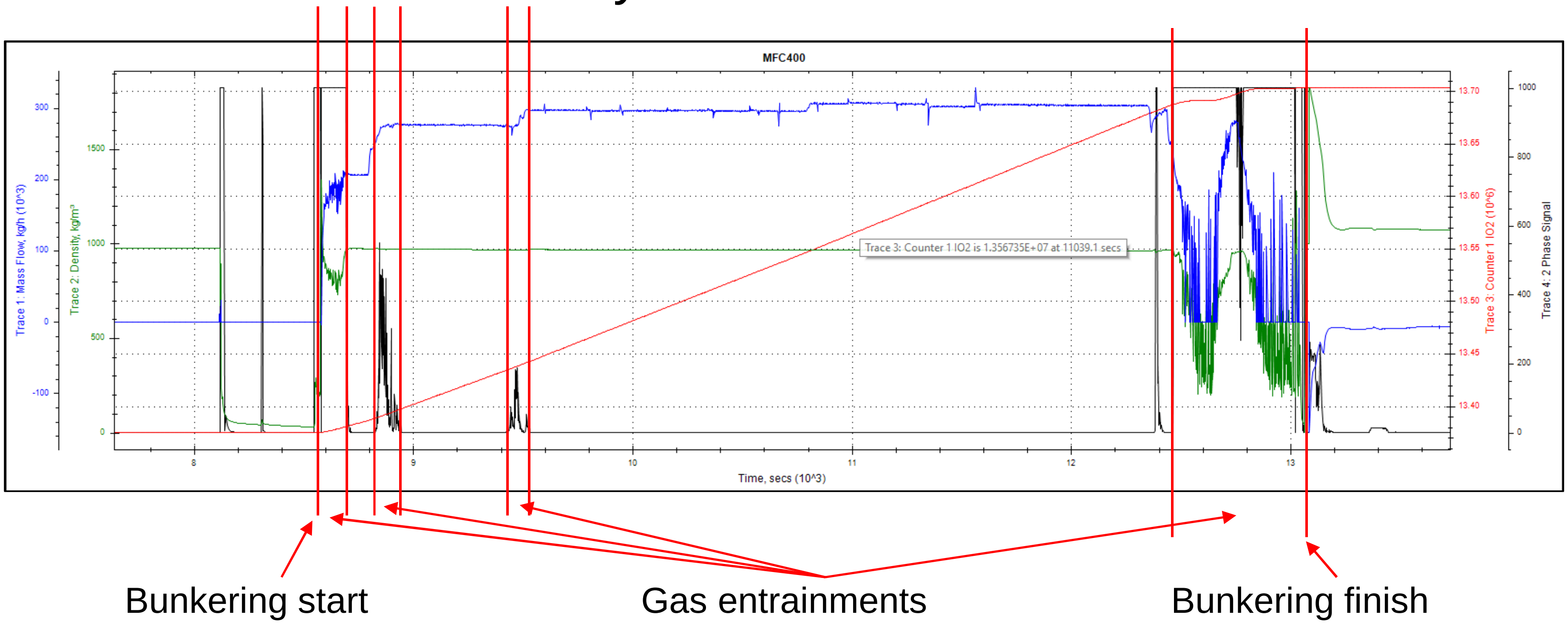




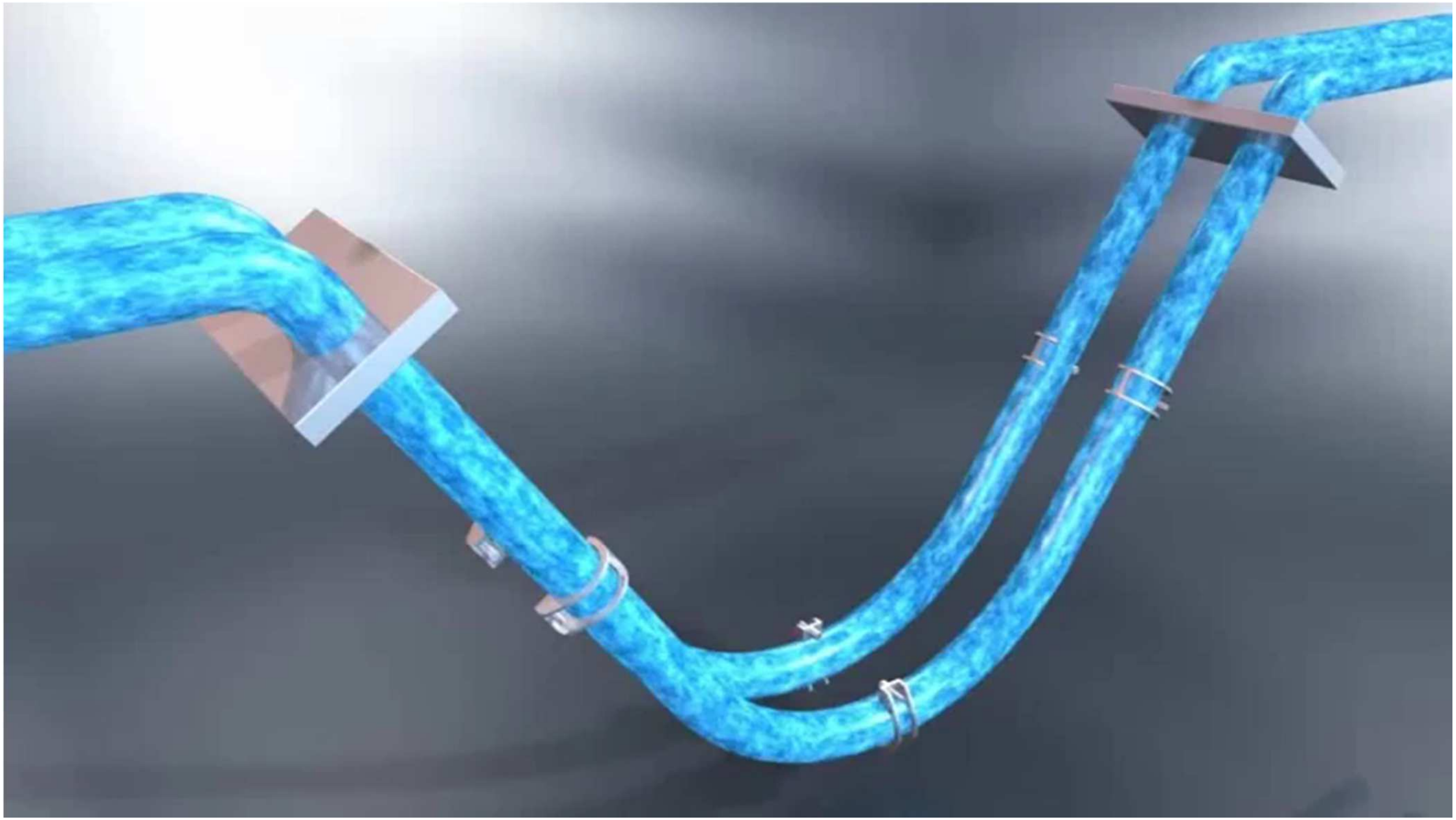
Introduction

Typical application scenario

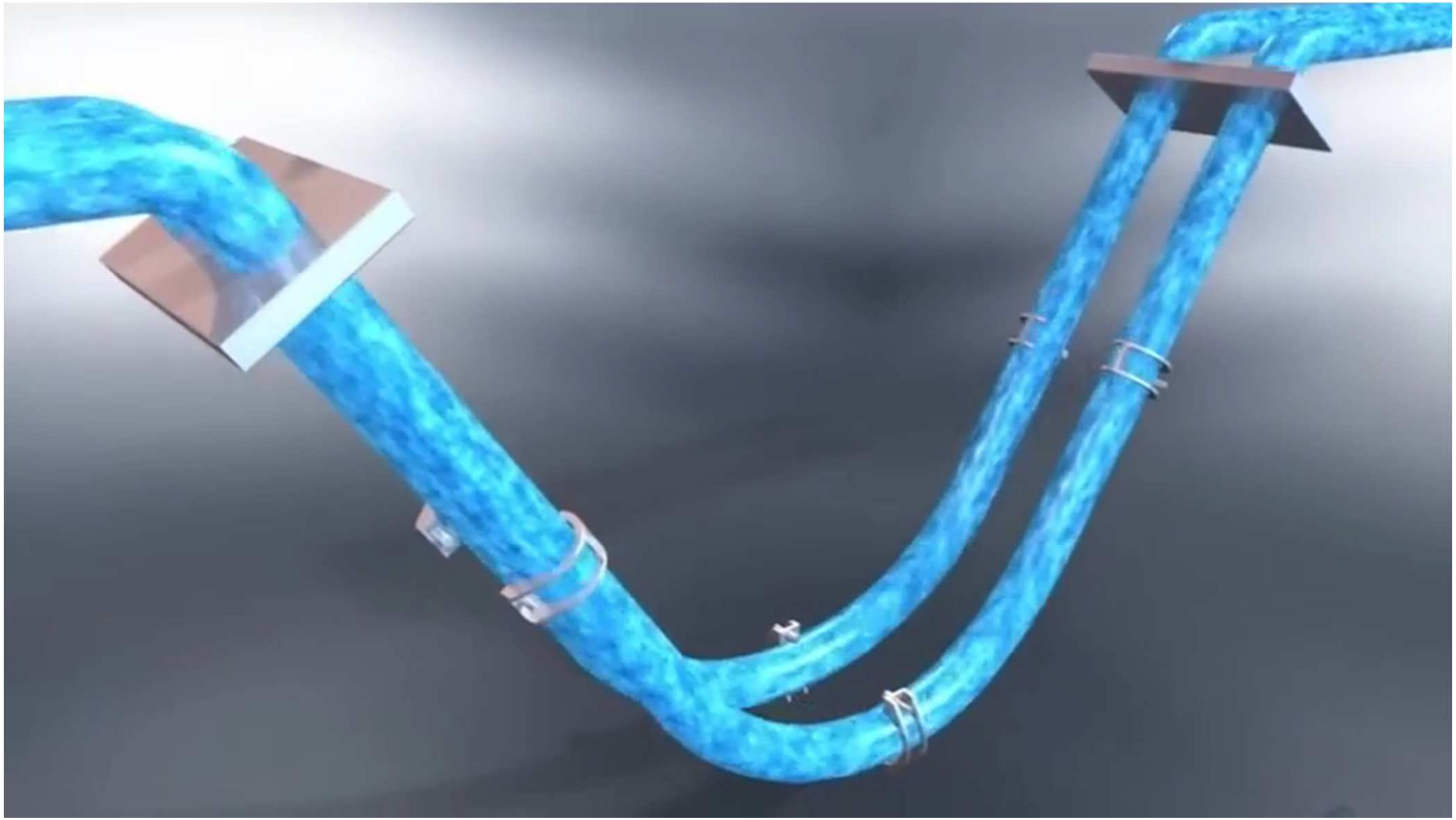
- 0.3% uncertainty under single-phase conditions
- 0.5% overall uncertainty



Introduction

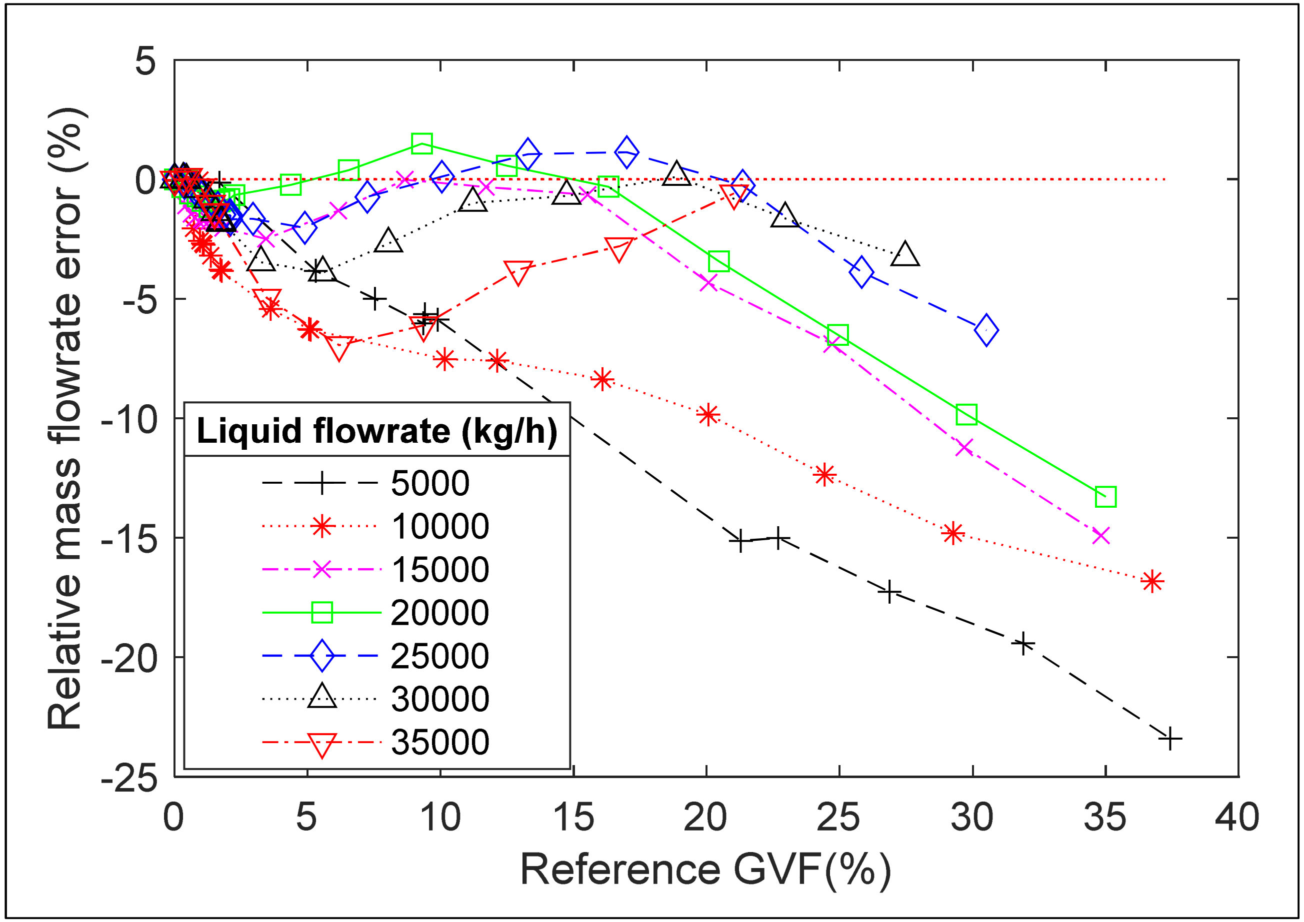


Introduction



Introduction

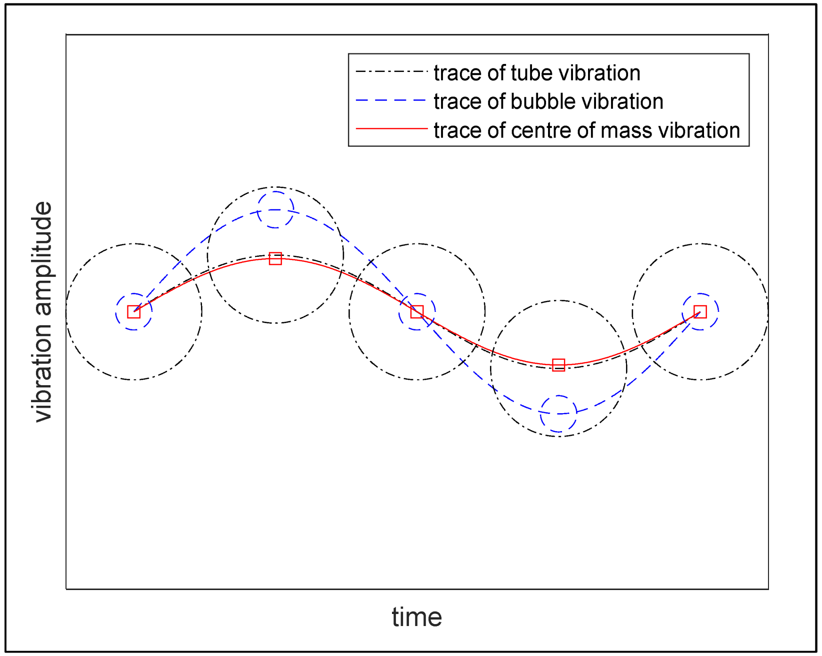
Typical error curve under gas-liquid two-phase flow

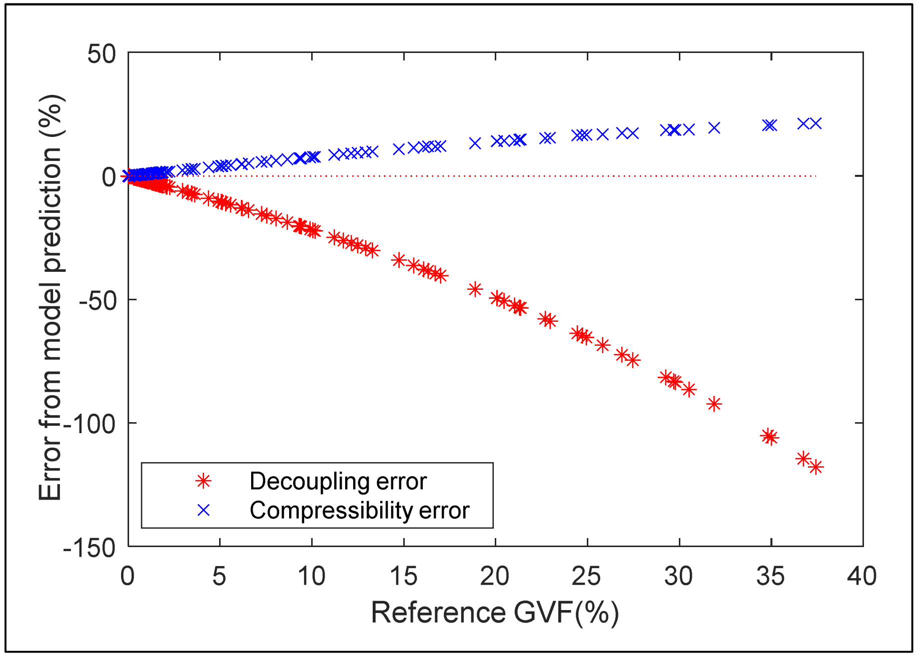


Methodology

Existing analytical models

- Decoupling error $$E_{d,q_m} = \frac{1-F}{1-\alpha}\alpha$$

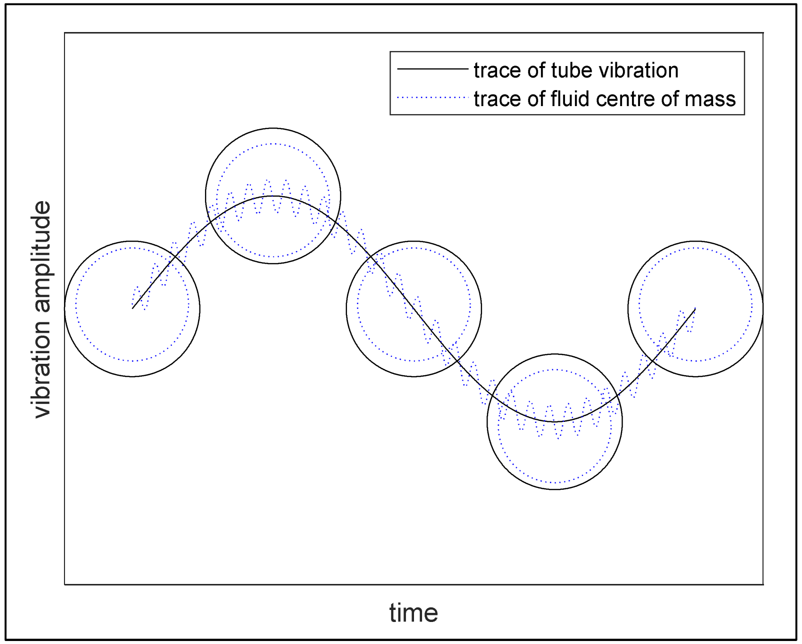


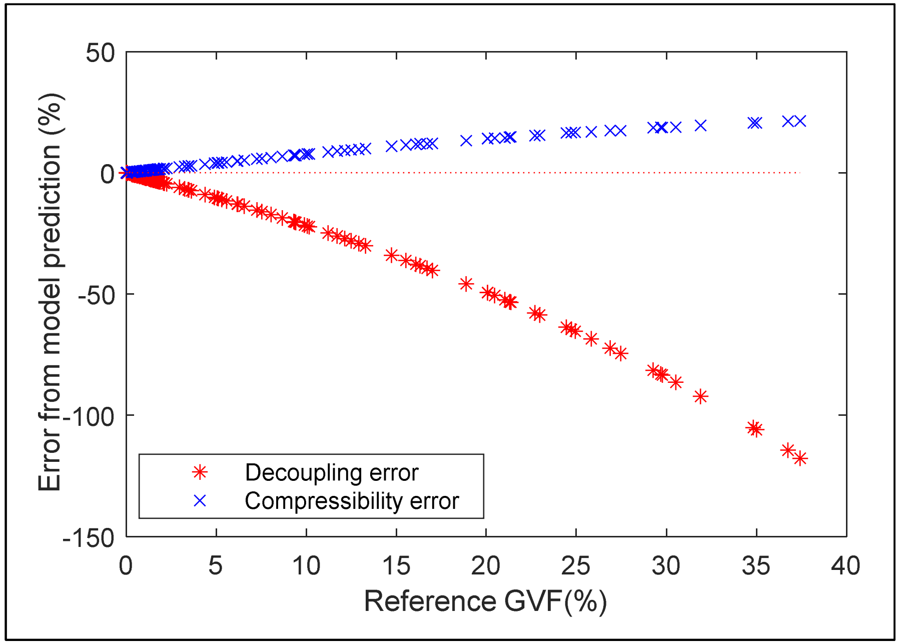


Methodology

Existing analytical models

- Compressibility error $E_{C,q_m} = \frac{1}{2}\left(\frac{\omega}{c}b\right)^2$

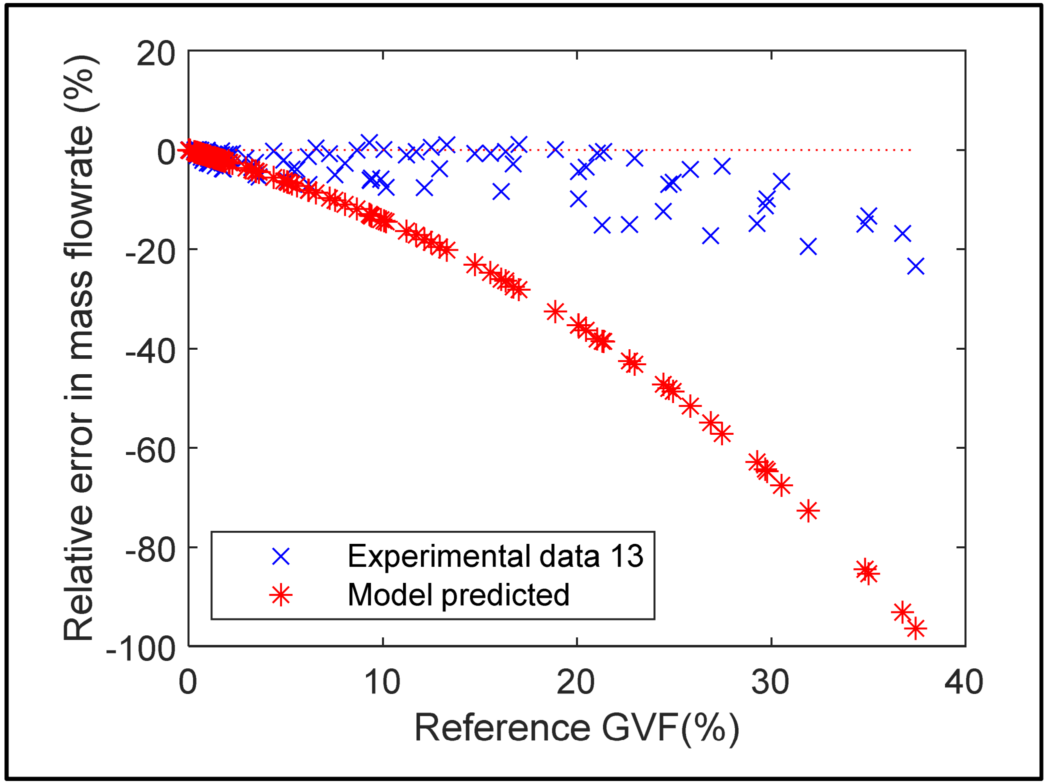




Methodology

Research Gap: factors not considered in existing models

- Decoupling error
  - GVF
  - Bubble size & distribution
- Compressibility error
  - Tube diameter
  - Vibration frequency
  - Speed of sound of fluid
- Damping
  - Liquid flowrate
  - Drive gain



Methodology

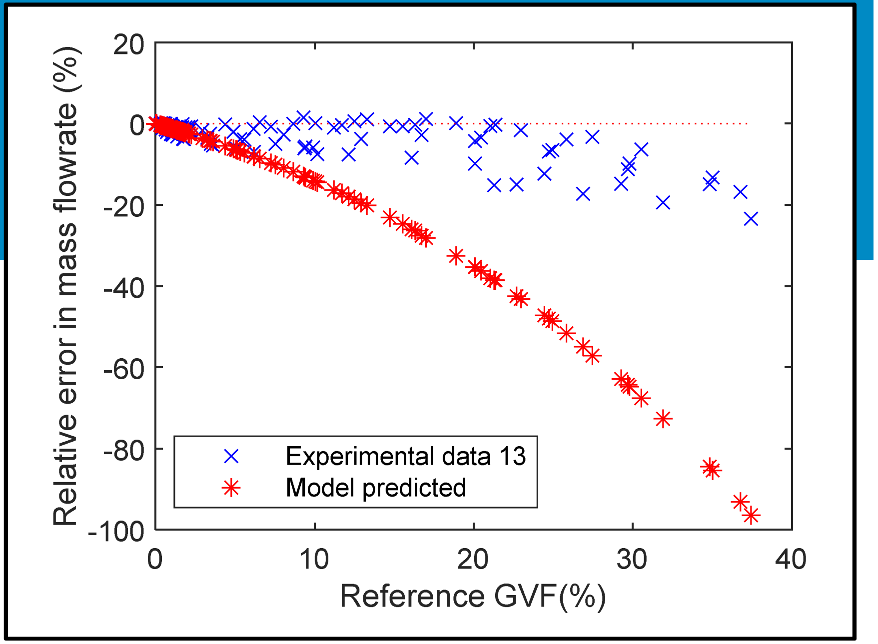
Improved analytical models

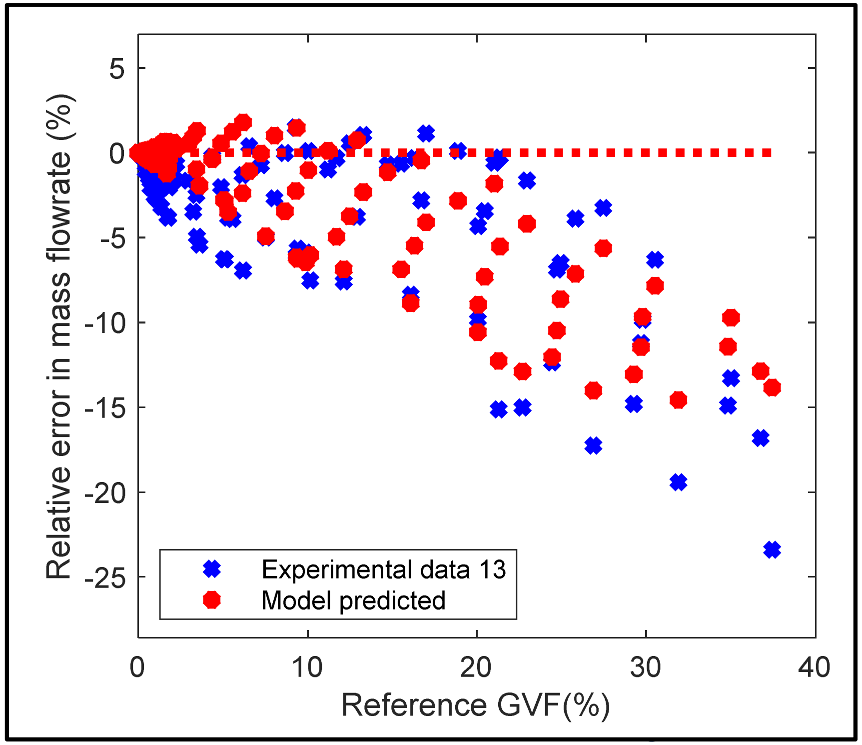
- Decoupling error

$$E_{d,q_m} = \frac{1-F'}{1-\alpha}\alpha;\ F' = C_F F(1-\alpha)$$

- Compressibility error
- Adding damping error term

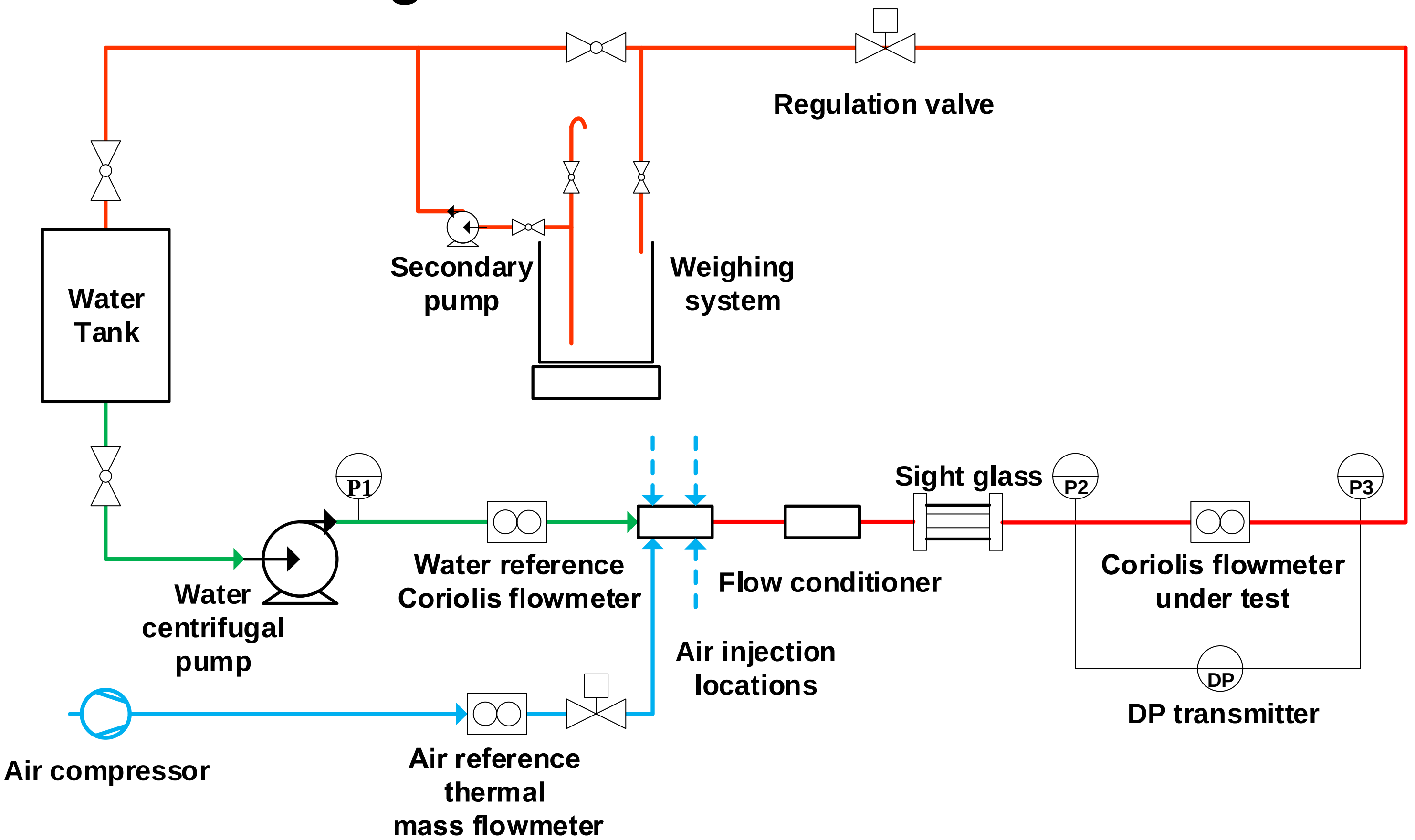
$$E_E = C_E\, G_D\, \alpha_{q_m}$$





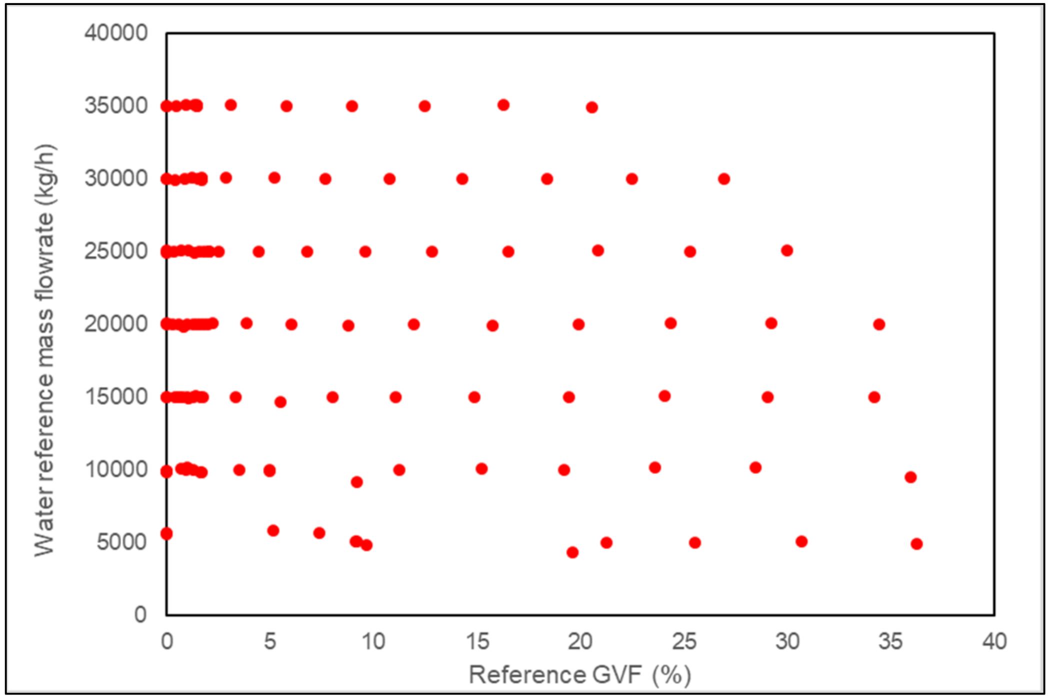
Experimental Work

Layout of the test rig



Experimental Work

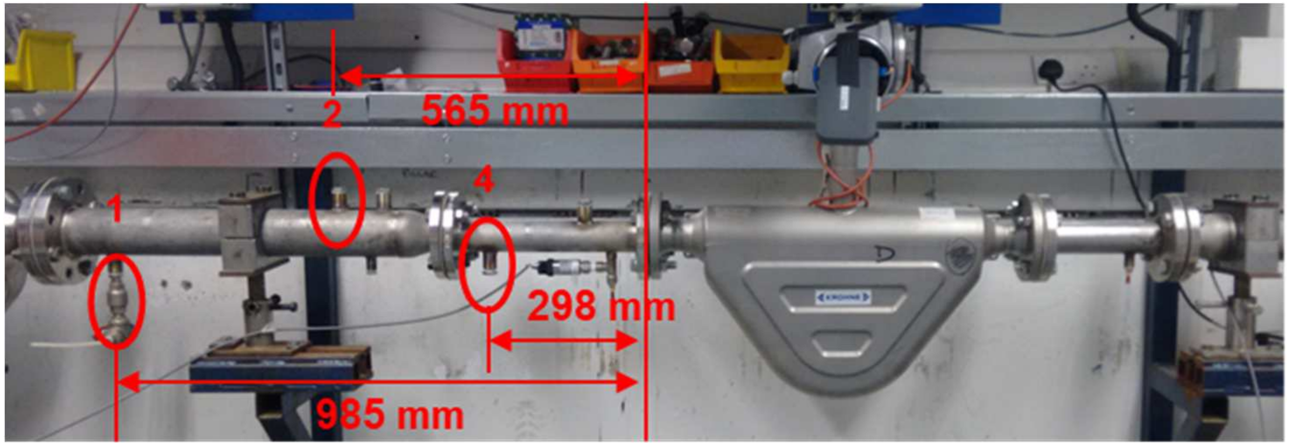
Test matrix

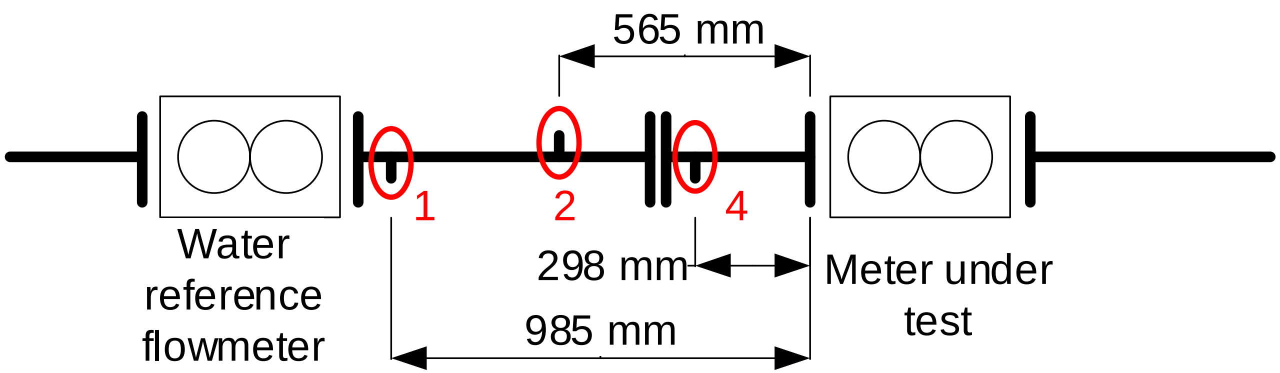


Data Sets	Injection Location	Flow conditioners	Temperature (°C)	Pressure (bar)
data01	1 bottom	Hybrid@2U	20	0.2
data02	1 bottom	Hybrid@4U	20	0.2
data03	1 top	Grid@4D	20	0.2
data04	1 top	Hybrid@2U	20	0.2
data05	1 top	Hybrid@4U	20	0.2
data06	2 bottom	Hybrid@2U	20	0.2
data07	2 bottom	Hybrid@4U	20	0.2
data08	2 top	Hybrid@2U	20	0.2
data09	2 top	Hybrid@4U	20	0.2
data10	1 top	no	20	0.2
data11	1 top	no	20	0.7
data12	1 top	no	40	0.2
data13	2 bottom	no	20	0.2
data14	2 bottom	no	20	0.7
data15	2 bottom	no	40	0.2
data16	1 bottom	no	20	0.2
data17	1 bottom	no	20	0.2
data18	2 top	no	20	0.2
data19	4 bottom	no	20	0.2
data20	1 top	no	20	0.2
data21	2 bottom	no	20	0.2
data22	1 top	no	20	0.2
data23	1 top	no	20	0.2
data24	2 bottom	no	20	0.2
data25	1 top	Swirl@2D	20	0.2
data26	2 bottom	Swirl@2D	20	0.2
data27	2 bottom	Grid@2D	20	0.2
data28	1 top	Grid@2D	20	0.2
data29	1 top	Grid@4D	20	0.2

Experimental Work

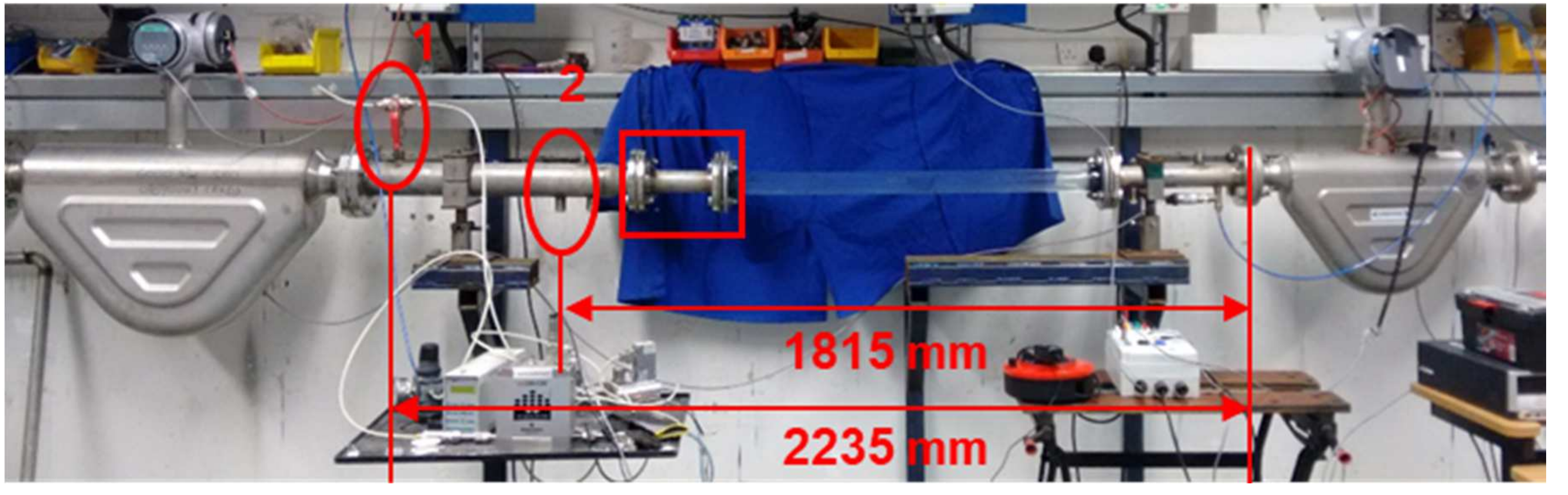
Typical test section (e.g. setup 1)

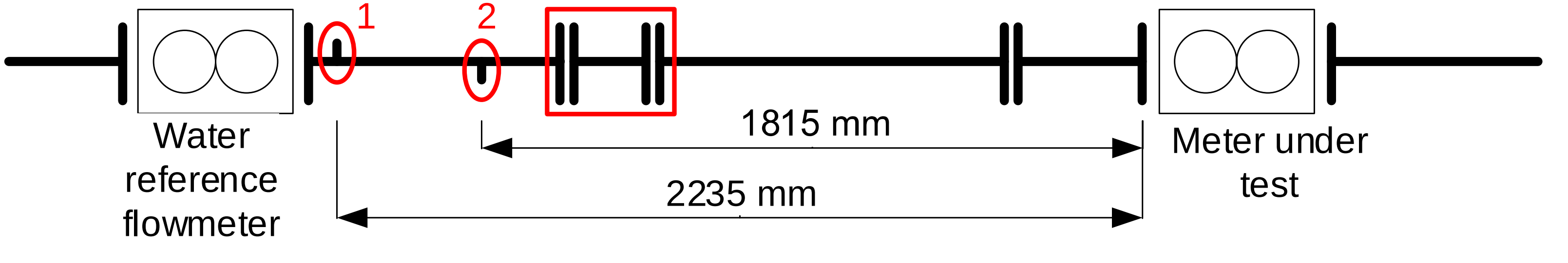




Experimental Work

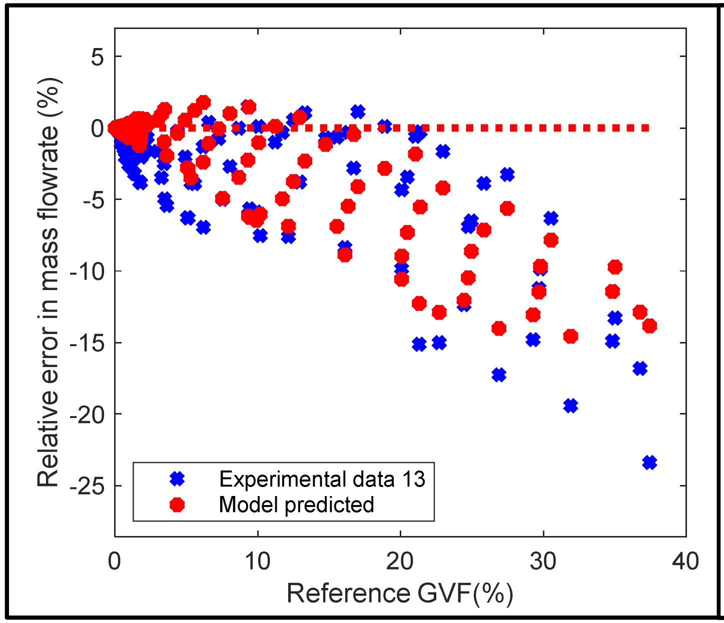
Typical test section (e.g. setup 3 & 4)

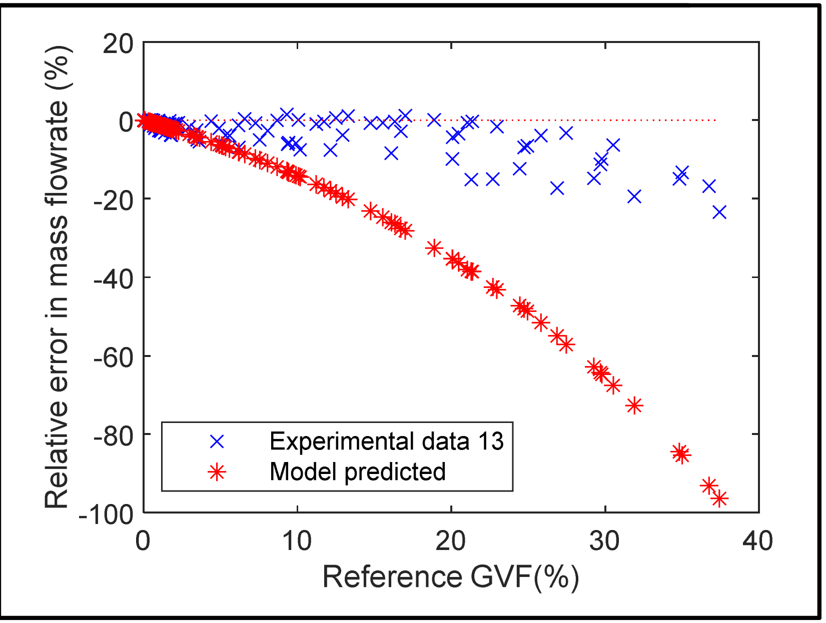




Data Interpretation

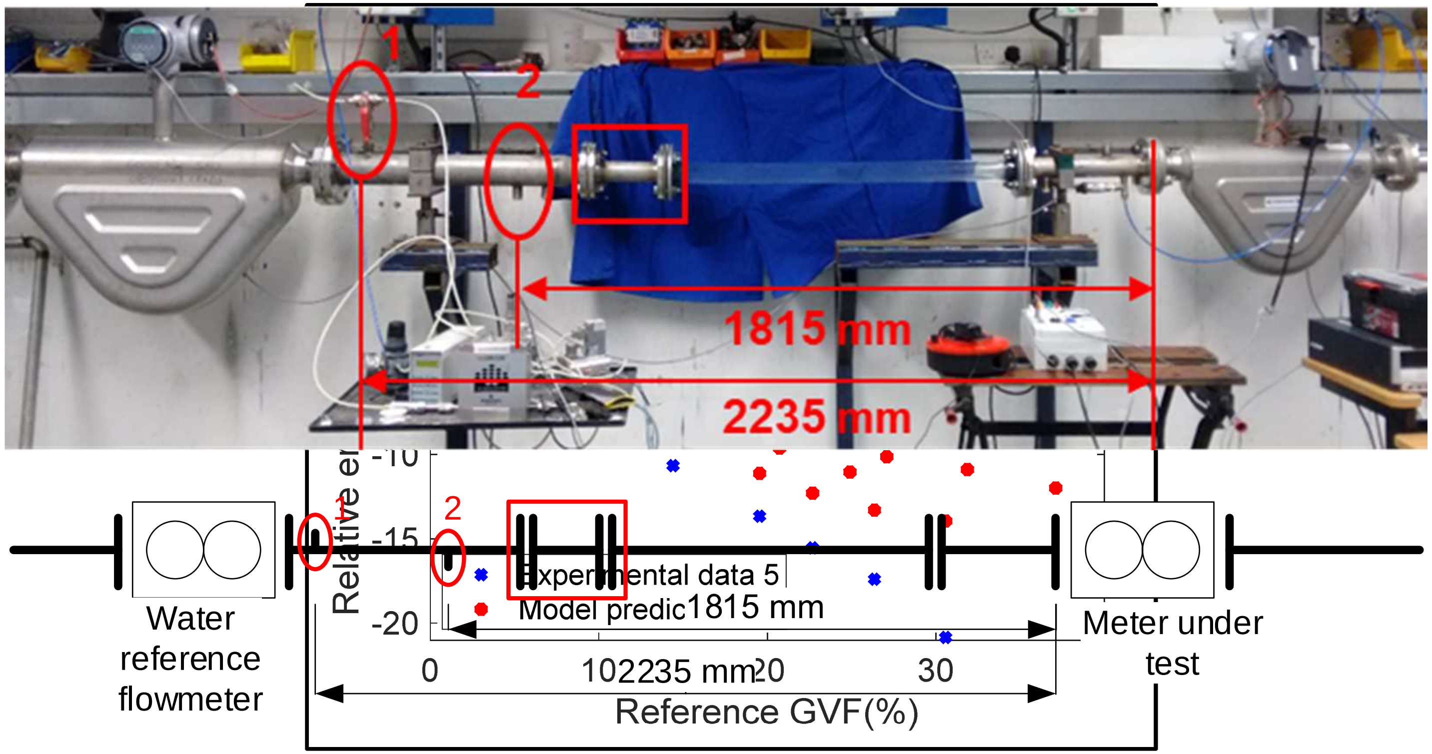
- For the majority test setups:
  - Mass relative error is within 10%
  - GVF absolute error is within 5% (refer to paper for details)
  - Application range extended from 15% GVF to at least 40% GVF





Data Interpretation

- For the minority test setups:
  - Cannot predict as accurate especially at high flowrate
  - Such test setups are not common in industry



Conclusions

- There are 2314 out of 2457 (94.2%) predictions of mass flowrate that are within 10% error
- There are 2403 out of 2457 (97.8%) predictions of GVF measurements are within 5% error
- The applicable range of the model is extended from maximum 15% GVF to at least 40% GVF
- A better understanding of the gas-liquid interaction inside the vibrating tubes of a Coriolis flowmeter is achieved.

Acknowledgement

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